

# Research on pricing strategy of dual-channel supply chain based on blockchain technology under carbon trading

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## ABSTRACT

In the context of the dual-carbon goal, it is of great significance to study the application of blockchain technology in the dual-channel supply chain under the carbon trading mechanism for the carbon emission reduction of enterprises and the overall profit maximization of the supply chain. In this paper, two decision models of the supply chain under secondary carbon trading are constructed to analyze the two cases of whether to adopt blockchain technology. Stackelberg model is used to study the impact of blockchain technology on the pricing decision of the dual-channel supply chain under carbon trading, and the two models are compared and analyzed. According to the research results, after the application of blockchain technology, wholesale prices, direct sales prices, retail prices, and profits of retailers and manufacturers have increased compared with the non-use of blockchain technology, which is conducive to promoting the development of carbon emission reduction for manufacturers.

## KEYWORDS

Blockchain technology; Dual channel supply chain; Pricing decision

## 1. INTRODUCTION

Under the guidance of the current environmental status and the "double carbon" goal, enterprises have opened the road of low-carbon transformation and developed emission reduction technologies for low-carbon production. And consumers are increasingly concerned about the low-carbon properties of products and are willing to pay higher prices for green products to promote environmental protection. With the rise of the Internet and e-commerce, consumers tend to shop online, and China also has corresponding policies to encourage the rational use of the Internet to sell green products to meet consumers' environmental protection consumption needs. Therefore, while maintaining traditional retail channels, many enterprises also use online direct sales channels, and are committed to achieving low-carbon production through energy conservation and emission reduction.

However, in the actual situation of the supply chain, the information of low-carbon products is not transparent to consumers and the source of products is difficult to track. Some enterprises may carry out false propaganda of low-carbon products in order to expand sales, which will cause low trust of consumers in low-carbon products. Blockchain is an innovative technology, it uses a distributed, decentralized way, with information cannot be changed, traceable, open and transparent. Its application in the low-carbon supply chain helps to meet consumers' demand for traceability of low-carbon products, thereby expanding the market scale of low-carbon products and improving market coverage. Therefore, this paper deeply discusses the impact of blockchain technology on the pricing decision of dual-channel supply chain, and comprehensively considers the value and cost of

implementing blockchain application for manufacturers, in order to provide theoretical reference for the application of blockchain technology.

## **2. REVIEW OF RELEVANT LITERATURE**

At present, many scholars at home and abroad have carried out a series of researches on pricing decision-making of low-carbon dual-channel supply chain and blockchain technology in the field of supply chain decision optimization.

In terms of low-carbon dual-channel supply chain pricing research, Li et al. [1] studied the impact of manufacturers' opening of online direct sales channels on the greenness and pricing of supply chain products in the context of low-carbon. Ji et al. [2] focused on the impact of consumers' low-carbon preference under the carbon trading mechanism, and how this impact affects the carbon emission reduction decisions of the supply chain. Zhou and Ye [3] studied the low-carbon dual-channel supply chain consisting of a single manufacturer and retailer, and analyzed the optimal strategy in the supply chain under different decision-making modes. Liang Xi et al. [4] studied the influence of consumer channel preferences under different structures in the manufacturer-led low-carbon dual-channel supply chain, and discussed the influence of such preferences on the optimal pricing and emission reduction strategies of manufacturers and retailers.

In terms of the application of blockchain technology in the supply chain, Selvakumari [5] found that blockchain can improve the information opacity among enterprises and improve management performance. Kshetri [6] discussed the impact of blockchain on the cost, quality and reliability of the supply chain. It is concluded that the application of blockchain technology can improve the transparency of supply chain and the responsibility of supply chain members. According to the research results of Yan Yan [7], it can be concluded that blockchain technology can promote information sharing among supply chain members, thus effectively improving the profit level of each member. Liu Liang et al. [8] used blockchain technology to reduce the extent to which manufacturers misrepresent freshness in the fresh product supply chain.

To sum up, pricing decisions of low-carbon dual-channel supply chains are affected by a variety of factors, including consumer preferences, carbon trading mechanisms, and carbon emission reduction cost sharing ratio. However, many studies fail to consider the impact of manufacturers' false reporting of carbon emission reduction information and consumers' trust in low-carbon products on pricing decisions. In terms of the application of blockchain technology in the supply chain, few parameters are introduced to study the impact on pricing decisions in the supply chain from the perspective of using blockchain technology to supervise the authenticity of manufacturers' carbon emissions and improve consumers' trust.

Based on this, this paper, based on the existing literature research, discusses the impact of blockchain technology on the decision-making of low-carbon dual-channel supply chain in two cases when manufacturers choose whether to use blockchain technology, and provides a useful reference for the promotion and application of blockchain technology in low-carbon production of enterprises.

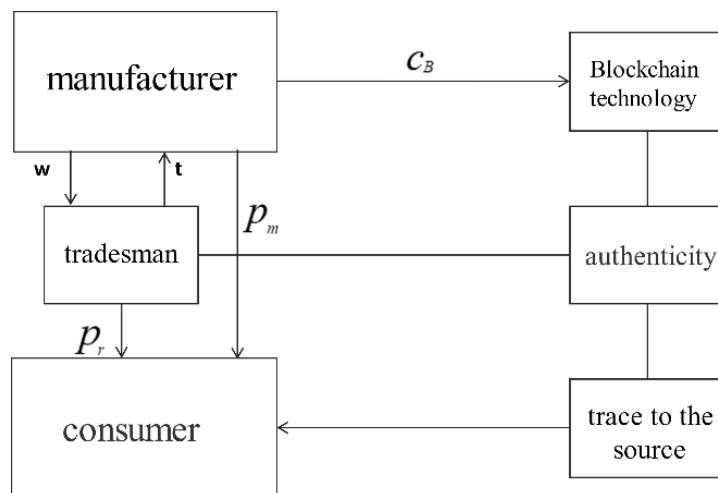
## **3. PROBLEM DESCRIPTION AND BASIC ASSUMPTIONS**

### **3.1. Problem Description**

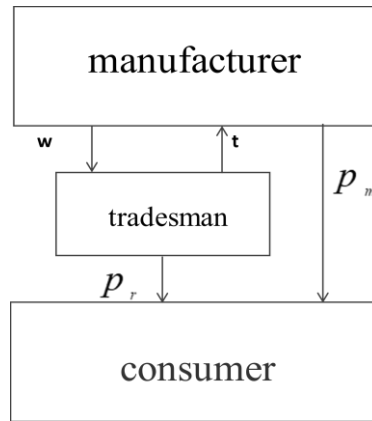
In the context of the carbon cap-and-trade scheme, manufacturers need to take action to reduce carbon emissions and invest in the development of carbon reduction technologies to reduce the carbon emissions of products in the production process. At the same time, retailers should actively participate in carbon emission reduction, consumers should pay more attention to low-carbon products when purchasing, and jointly promote the development of low-carbon supply chain. Under the current

carbon trading mechanism, the environmental protection department of the government allocates a certain amount of free quotas to enterprises. If the carbon emission of the products in the production process is higher than the quota, the enterprises need to purchase the excess credits in the carbon trading market; on the contrary, if the carbon emission is lower than the quota, the remaining credits can be sold in the carbon trading market. In view of consumers' trust in the authenticity of low-carbon products and their traceability needs, manufacturers can choose to adopt blockchain technology, record the production and processing information of low-carbon products and carbon emissions to the relevant blockchain platform, and conduct quality certification of low-carbon products. Consumers can obtain original information such as production and processing, raw materials and carbon emissions of low-carbon products through relevant blockchain traceability platforms. Considering the application value and implementation cost of blockchain, manufacturers can choose whether to implement blockchain technology to enhance consumer trust and meet consumer product traceability needs.

Based on the above analysis, this paper explores a dual-channel low-carbon supply chain system consisting of a single manufacturer and retailer. Among them, the low-carbon products produced by manufacturers are both wholesale to retailers through traditional retail channels, and open online direct sales channels. In the supply chain, the manufacturer plays a leading role, first deciding whether to adopt blockchain technology, and determining the price of wholesale to retailers and direct sales prices, and as a follower, the retailer then determines the selling price of the product. According to whether blockchain technology is adopted or not, it is divided into adopting blockchain technology model ( $Y$ ) and not adopting blockchain technology model ( $N$ ) as shown in the following figure. The optimal pricing decision of manufacturer and retailer is studied by backward induction to solve the game model.



**Figure 1.** Adopt the blockchain technology model



**Figure 2.** Do not adopt the blockchain technology model

### 3.2. Basic Assumption

This article considers the following situations:

- (1) The competition between traditional retail channels and direct sales channels for market share is becoming more and more fierce, and consumers have different payment intentions for different channels.  $h$  represents the proportion of market share held by traditional retail channels ( $0 < h < 1$ ),  $b$  ( $0 < b < 1$ ) represents the cross-elastic price coefficient between two channels.
- (2) Assuming that only a single low-carbon product is sold and only the manufacturer's carbon emissions in the production process are considered, the carbon emission reduction cost is a quadratic function of the carbon emission reduction per unit product, expressed as  $c_e = ke^2 / 2$ ,  $k$  is the cost factor of carbon emission reduction.
- (3) In order to simplify the complexity of the analysis, this paper assumes that the production cost of the manufacturer's product is 0 [9], which will not affect the relevant conclusions of this paper.
- (4) In addition, assuming that the market base demand scale of low-carbon products is  $a = 1$  [10], the complexity of the simplified model will not affect the relevant conclusions of this paper. Consumers all have low-carbon preferences, and its coefficient is  $\theta$ .
- (5) When manufacturers choose not to adopt blockchain technology, on the one hand, it will reduce the degree of consumer preference for low-carbon products, and on the other hand, there may be a case of carbon emissions misreporting. Therefore, this paper introduces low-carbon preference discount factor  $\mu$  ( $0 < \mu < 1$ ) and carbon emission lying factor  $\gamma$  ( $0 < \gamma < 1$ ) to measure its impact.
- (6) This paper assumes that the demand and supply of low-carbon products are in equilibrium.

### 3.3. Symbol specification

The relevant parameters and meanings of this paper are shown in the following table:

**Table 1.** Parameter symbol and meaning

Parameter symbol	implication
$h$	The market share of traditional retail channels
$b$	Cross elastic price coefficient
$e$	Carbon reduction
$k$	Carbon reduction cost factor
$\theta$	Low carbon preference coefficient
$\mu$	Low carbon preference discount factor
$\gamma$	Carbon emission misreporting factor ( $1-\gamma$ Indicates the degree of carbon emission misreporting, the closer $\gamma$ is to 0, the higher the degree of misreporting, and $\gamma=1$ means truthfully reported)
$c_0$	Unit carbon trading price
$M$	Carbon emission coefficient per unit product
$a_m$	Carbon quota coefficient
$w$	Wholesale price
$c_B$	Blockchain cost per unit product
$p_r$	Retail prices for retail channels
$p_m$	Direct selling price of online direct selling channel
$D_r$	Market demand for low-carbon products in retail channels
$D_m$	Market demand for low-carbon products in direct sales channels
$\Pi_r$	Retailer profit
$\Pi_m$	Manufacturer's profit

#### 4. CONSTRUCTION OF DUAL-CHANNEL SUPPLY CHAIN DECISION MODEL BASED ON BLOCKCHAIN TECHNOLOGY

##### 4.1. Dual-channel Supply Chain Decision-Making Model Without Blockchain Technology(N)

The demand function of traditional retail channel and online direct selling channel is respectively:

$$D_r^N = h - p_r^N + bp_m^N + \theta(1 - \mu)e \quad (1)$$

$$D_m^N = (1 - h) - p_m^N + bp_r^N + \theta(1 - \mu)e \quad (2)$$

The profit function of the retailer and the manufacturer is:

$$\Pi_r^N = (p_r^N - w^N)D_r^N \quad (3)$$

$$\Pi_m^N = w^N D_r^N + p_m^N D_m^N - ke^2 / 2 - c_0(\gamma M(D_r^N + D_m^N) - a_m) \quad (4)$$

The manufacturer's profit is equal to the total revenue  $w^N D_r^N + p_m^N D_m^N$  from wholesale sales to retailers and online direct sales, minus the emission reduction cost  $ke^2 / 2$ , and minus (or plus) the cost (or revenue)  $c_0(\gamma M(D_r^N + D_m^N) - a_m)$  of the carbon market. The retailer's profit is equal to the total revenue  $p_r^N D_r^N$  of the products sold in the retail channel minus the wholesale cost  $w^N D_r^N$ .

By backward induction, formula (1) is substituted into formula (3) and the first partial derivative of  $p_r^N$  is obtained. The retailer's price response function can be obtained by solving  $\frac{\partial \Pi_r^N}{\partial p_r^N} = 0$ :

$$p_r^N = (-e(\mu-1)\theta + bp_m^N + h + w^N) / 2 \quad (5)$$

By substituting equation (5) into equation (4) to solve the Hessian matrix of manufacturer's profit regarding the wholesale price and direct price of low-carbon products, it can be concluded that:

$$H(\Pi_m^N(p_m^N, w^N)) = \begin{pmatrix} \frac{\partial^2 \Pi_m^N}{\partial p_m^{N2}} & \frac{\partial^2 \Pi_m^N}{\partial p_m^N \partial w^N} \\ \frac{\partial^2 \Pi_m^N}{\partial w^N \partial p_m^N} & \frac{\partial^2 \Pi_m^N}{\partial w^{N2}} \end{pmatrix} \\ = \begin{pmatrix} b^2 - 2 & b \\ b & -1 \end{pmatrix}$$

Because  $b^2 - 2 < 0$  and  $2 - 2b^2 > 0$  show that Hessian matrix is negative definite matrix, and  $\Pi_m^N$  has a maximum value. By solving equations  $\frac{\partial \Pi_m^N}{\partial p_m^N} = 0$  and  $\frac{\partial \Pi_m^N}{\partial w^N} = 0$  together, the optimal pricing strategies of product wholesale price and online direct selling price can be obtained as follows:

$$w^{N*} = \frac{Bb^2 + bA - B + A + bh - b - h}{2b^2 - 2} \quad (6) \\ p_m^{N*} = \frac{(b^2 - 2)(Bb^2 + (A - h)b + A - B + h - 1)}{2b^4 - 6b^2 + 4}$$

Finally, by substituting (6) into the retailer's price response function, the optimal retail price strategy can be obtained as follows:

$$p_r^{y*} = \frac{(Eb + E + (\theta e + h)b^2 + (-Mc_0 - 2\theta e + 2h - c_B - 2)b - Mc_0 - 3\theta e - 3h - c_B)}{4(b^2 - 1)} \quad (7)$$

Among them,  $A = e(\mu - 1)\theta$ ,  $B = M\gamma c_0$ .

In models that do not use blockchain technology:

$$\frac{\partial w^N}{\partial M} > 0, \quad \frac{\partial w^N}{\partial \mu} < 0, \quad \frac{\partial w^N}{\partial \gamma} > 0, \quad \frac{\partial w^N}{\partial e} > 0, \quad \frac{\partial w^N}{\partial h} > 0, \quad \frac{\partial w^N}{\partial \theta} > 0 \\ \frac{\partial p_m^N}{\partial M} > 0, \quad \frac{\partial p_m^N}{\partial \mu} > 0, \quad \frac{\partial p_m^N}{\partial \gamma} > 0, \quad \frac{\partial p_m^N}{\partial e} > 0, \quad \frac{\partial p_m^N}{\partial h} < 0, \quad \frac{\partial p_m^N}{\partial \theta} > 0 \\ \frac{\partial p_r^N}{\partial M} > 0, \quad \frac{\partial p_r^N}{\partial \mu} < 0, \quad \frac{\partial p_r^N}{\partial \gamma} > 0, \quad \frac{\partial p_r^N}{\partial e} > 0, \quad \frac{\partial p_r^N}{\partial h} > 0, \quad \frac{\partial p_r^N}{\partial \theta} > 0 \\ \frac{\partial d_r^N}{\partial \mu} < 0, \quad \frac{\partial d_m^N}{\partial \mu} < 0 (\sqrt{3} - 1 < b < 1), \quad \frac{\partial d_r^N}{\partial \theta} > 0, \quad \frac{\partial d_m^N}{\partial \theta} > 0 (0 < b < \sqrt{3} - 1)$$

The above analysis shows that: when the blockchain technology is not used, with the increase of carbon emission coefficient per unit product, the wholesale price, online direct selling price, and retail price will increase; The carbon emission coefficient per unit product of the manufacturer is related to the carbon emission reduction technology. If the carbon emission reduction technology of the manufacturer is relatively backward, the carbon emission reduction is proportional to the wholesale price, online direct selling price and retail price. Therefore, with the increase of carbon emission reduction, the manufacturer needs to bear higher carbon emission reduction cost, which leads to the increase of wholesale price, online direct selling price and retail price. The market demand of traditional retail channels is inversely proportional to the low carbon preference discount factor. When  $\sqrt{3}-1 < b < 1$ , the market demand of online direct marketing channels is inversely proportional to the low carbon preference discount factor. With the increase of the carbon preference discount factor factor, the wholesale price and retail price will be reduced to make up for the decline in consumers' carbon preference caused by the non-adoption of blockchain technology. Manufacturers will raise the price of direct sales online.

In addition, with the increase of the carbon emission misreporting factor, the lower the degree of carbon emission misreporting, the manufacturers will increase the carbon trading expenditure, which will also increase the wholesale price, direct sales price and retail price. When consumers are more inclined to traditional retail channels, the wholesale price and retail price will be relatively increased, in order to seize the market share of low-carbon products, manufacturers will also reduce the price of online direct sales to attract more customers to buy. As consumer preferences for low-carbon products increase, wholesale prices, direct sales prices and retail prices will also increase, while market demand for traditional retail channels will also increase. When  $0 < b < \sqrt{3}-1$ , the preference of consumers for low-carbon products becomes more significant, which will promote the growth of market demand for online direct marketing channels.

By substituting formula (6) and (7) into formula (3) and (4), the maximum profit of retailers and manufacturers is:

$$\Pi_r^* = \frac{(Bb - B - A + h)^2 (b+1)^2 (b-1)^2}{16(b^2 - 1)^2} \quad (8)$$

$$\begin{aligned} \Pi_m^* = & -\frac{1}{8(b^2 - 1)^2} \left( (b+1)(b-1) (B^2 b^4 + 2Mc_0(-A+B+h)\gamma b^3 + (((\mu-1)^2 \theta^2 + 4k)e^2 - 6A \left( B + \frac{h}{3} \right) - 4B^2 + (-2M(h-2)\gamma - 8a_m)c_0 + h^2) b^2 \right. \\ & \left. + (4A^2 + 2A(B-2) - 2B^2 - 2Bh - 4h^2 + 4h)b + X \right) \end{aligned} \quad (9)$$

Among them,  $A = e(\mu-1)\theta$ ,  $B = M\gamma c_0$ ,

$$X = (3(\mu-1)^2 \theta^2 - 4k)e^2 + 6\theta(\mu-1) \left( M\gamma c_0 + \frac{h}{3} - \frac{2}{3} \right) e + 3M^2 \gamma^2 c_0^2 + (2M(h-2)\gamma + 8a_m)c_0 + 3h^2 - 4h + 2 \Big) / (-8(b^2 - 1)^2)$$

## 4.2. Dual-channel Supply Chain Decision Model Using Blockchain Technology(Y)

The demand functions of traditional retail channels and online direct selling channels are as follows:

$$D_r^Y = h - p_r^Y + bp_m^Y + \theta e \quad (10)$$

$$D_m^Y = (1-h) - p_m^Y + bp_r^Y + \theta e \quad (11)$$

At this time, the profit function of the retailer and the manufacturer is:

$$\Pi_r^Y = (p_r^Y - w^Y)D_r^Y \quad (12)$$

$$\Pi_m^Y = (w^Y - c_B)D_r^Y + (p_m^Y - c_B)D_m^Y - k(e^Y)^2 / 2 - c_0(M(D_r^Y + D_m^Y) - a_m) \quad (13)$$

Among them, the profit of the manufacturer, on the basis of the profit function without the use of blockchain technology, also needs to subtract the technical cost required by the manufacturer to adopt blockchain technology  $c_B(D_r^Y + D_m^Y)$ . The profit function for retailers is the same as it would be without blockchain technology, which is revenue from sales minus wholesale costs.

By backward induction, the demand function of the retail channel is substituted into the profit function of the retailer, and the first-order partial derivative of  $p_r^Y$  is obtained. The price response function of the retailer can be obtained by solving  $\frac{\partial \Pi_r^Y}{\partial p_r^Y} = 0$  as follows:

$$p_r^Y = (bp_m^N + \theta e + h + w^Y) / 2 \quad (14)$$

By substituting equation (14) into equation (13) to solve the Hessian matrix of manufacturer's profit regarding the wholesale price and direct price of low-carbon products, we can get:

$$\begin{aligned} H(\Pi_m^Y(p_m^Y, w^Y)) &= \begin{pmatrix} \frac{\partial^2 \Pi_m^Y}{\partial p_m^{Y2}} & \frac{\partial^2 \Pi_m^Y}{\partial p_m^Y \partial w^Y} \\ \frac{\partial^2 \Pi_m^Y}{\partial w^Y \partial p_m^Y} & \frac{\partial^2 \Pi_m^Y}{\partial w^{Y2}} \end{pmatrix} \\ &= \begin{pmatrix} b^2 - 2 & b \\ b & -1 \end{pmatrix} \end{aligned}$$

It can be seen from the above section that this Hesse matrix is negative definite, so  $\Pi_m^Y$  has a maximum value. By solving the equations of  $\frac{\partial \Pi_m^Y}{\partial p_m^Y} = 0$  and  $\frac{\partial \Pi_m^Y}{\partial w^Y} = 0$  together, the optimal pricing strategies of product wholesale price and online direct selling price can be obtained as follows:

$$\begin{aligned} w^{Y*} &= \frac{E + (-\theta e + h - 1)b - Mc_0 - \theta e - h - c_B}{2b^2 - 2} \\ p_m^{Y*} &= \frac{(E + (-\theta e - h)b - Mc_0 - \theta e + h - c_B - 1)(b^2 - 2)}{2b^4 - 6b^2 + 4} \end{aligned} \quad (15)$$

Finally, by substituting (15) into the retailer's price response function, the optimal pricing strategy of retail price can be found as follows:

$$p_r^{Y*} = \frac{(Eb + E + (\theta e + h)b^2 + (-Mc_0 - 2\theta e + 2h - c_B - 2)b - Mc_0 - 3\theta e - 3h - c_B)}{4(b^2 - 1)} \quad (16)$$

Among them,  $E = (Mc_0 + c_B)b^2$ .

In the model using blockchain technology:

$$\frac{\partial w^Y}{\partial M} > 0, \quad \frac{\partial w^Y}{\partial e} > 0, \quad \frac{\partial w^Y}{\partial h} > 0, \quad \frac{\partial w^Y}{\partial \theta} > 0$$

$$\begin{aligned}\frac{\partial p_m^Y}{\partial M} > 0, \quad \frac{\partial p_m^Y}{\partial e} > 0, \quad \frac{\partial p_m^Y}{\partial h} < 0, \quad \frac{\partial p_m^Y}{\partial \theta} > 0 \\ \frac{\partial p_r^Y}{\partial M} > 0, \quad \frac{\partial p_r^Y}{\partial e} > 0, \quad \frac{\partial p_r^Y}{\partial h} > 0, \quad \frac{\partial p_r^Y}{\partial \theta} > 0 \\ \frac{\partial d_r^Y}{\partial \theta} > 0, \quad \frac{\partial d_m^Y}{\partial \theta} > 0\end{aligned}$$

The above analysis shows that: when the blockchain technology is adopted, the carbon emission coefficient and carbon emission reduction per unit product are proportional to the wholesale price, online direct sales price, and retail price; As is the case without the blockchain technology model, if consumers prefer traditional retail channels, wholesale and retail prices may be relatively high, resulting in manufacturers having to lower online direct sales prices in order to capture market share for low-carbon products. Therefore, with the increasing demand of consumers for low-carbon products, the demand for traditional retail channels and online direct sales channels will become increasingly large. As a result, wholesale, online direct sales and retail prices will be higher.

By substituting formula (15) and (16) into formula (12) and (13), the maximum profit of retailer and manufacturer can be obtained respectively:

$$\Pi_r^{Y*} = \frac{((b-1)c_B + M(b-1)c_0 + \theta e + h)^2}{16} \quad (17)$$

$$\begin{aligned}\Pi_m^* = & -\frac{1}{8(b-1)(b+1)} \left( (Mc_0 + c_1)^2 b^4 + 2(Mc_0 + c_1)(Mc_0 + \theta e + h + c_1)b^3 + (-4M^2c_0^2 + (6Me\theta - 8Mc_1 + (-2h+4)M - 8a_m)c_0 \right. \\ & \left. + (\theta^2 + 4k)e^2 + 2\theta(h+3c_1)e - 4c_1^2 + (-2h+4)c_1 + h^2)b^2 + (-2M^2c_0^2 - 2M(\theta e + h + 2c_1)c_0 + 4e^2\theta^2 - 2\theta(c_1 - 2)e - 4h^2 - 2hc_1 - 2c_1^2 + 4h)b + Z \right) \quad (18)\end{aligned}$$

Among them,

$$Z = ((3M^2c_0^2 + (-6Me\theta + 6Mc_1 + (2h-4)M + 8a_m)c_0 + (3\theta^2 - 4k)e^2 - 2\theta(h+3c_1-2)e + 3c_1^2 + (2h-4)c_1 + 3h^2 - 4h + 2)) / (-8(b^2 - 1))$$

After solving the optimal pricing decision of model *N* and model *Y* in the low-carbon dual-channel supply chain system, and comparing the two situations, it is found that the wholesale price, direct sales price, retail price, and the profits of manufacturers and retailers are higher in the case of adopting blockchain technology than in the case of not adopting blockchain technology.

## 5. CONCLUSION

The conclusions of this study are as follows:

(1) Regardless of whether blockchain technology is adopted or not, the carbon emission reduction per unit carbon emission coefficient of low-carbon products and the increase of consumer preference for low-carbon products may lead to the increase of wholesale prices, direct sales prices and retail prices. At the same time, with the increase of consumer preference for traditional channels, it may lead to an increase in wholesale and retail prices, as well as a decrease in direct sales prices.

(2) When the blockchain technology is not adopted, when *b* is at a certain threshold, the carbon preference discount factor will negatively affect the market demand for low-carbon products, and the price will also be affected accordingly, and there may be a case of carbon emission misreporting. The higher the carbon emission factor, the manufacturer's wholesale price, online direct selling price and retail price will also increase.

(3) After the adoption of blockchain technology, consumers' preference for low-carbon products is proportional to the market demand for low-carbon products, while without the adoption of blockchain technology, when  $b$  is within a certain threshold range, the market demand for low-carbon products is proportional to consumers' preference for low-carbon products.

(4) With the introduction of blockchain technology, wholesale prices, direct sales prices, retail prices, and the profits of manufacturers and retailers are higher than they would be without blockchain technology.

Based on the above analysis, the application of blockchain technology in the dual-channel supply chain can provide us with important inspirations and lessons:

(1) The introduction of blockchain authentication technology and the establishment of a mutual trust mechanism based on its information immutable characteristics can effectively improve the information asymmetry between the supply chain and consumers, so the authenticity of carbon emissions can be monitored. Consumers' preference for low-carbon products can increase market demand and promote the development of emission reduction technologies for manufacturers. In order to meet the needs of consumers for low-carbon product information.

(2) By adopting blockchain technology, manufacturers can implement differentiated product strategies to improve product competitiveness and gain an advantage in channel competition, thereby increasing overall product sales and improving overall supply chain profits. In addition, members of the supply chain can actively cooperate to reduce the application cost of blockchain technology and achieve a win-win situation.

(3) As consumer preferences change, so do pricing strategies. When consumers are more inclined to traditional channels, manufacturers should pay attention to traditional retail and actively expand this market, while moderately reducing direct sales prices to seek greater profits. For retailers, access to high-quality and reasonably priced goods is very critical, which requires retailers to have keen observation and excellent negotiation skills to enhance their competitiveness.

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